smaller than it is above. The head and collar pale yellowish white; the thorax, tegulæ, and the base of the abdomen silvery white; the abdomen yellowish white, darker at the anus and on the underside; the legs and antennæ pale fawn-colour. Expanse 2 inches.

Hab. Ecuador, Sarayacu (*Buckley*); Zamora, September (*in coll. Mons. P. Dognin*).

This very beautiful species is quite distinct from any known to me.

XII.—Ramulina parasitica, *a new Species of Fossil Foraminifera infesting* Orbitolites Mantelli, *var.* Theobaldi, *with Comparative Observations on the Process of Reproduction in the Mycetozoa, Freshwater Rhizopoda, and Foraminifera.* By H. J. Carter, F.R.S. &c.

[Plate VIII.]

Ramulina parasitica, n. sp. (fossil).

Test thin, calcareous. Consisting individually of a single chamber (Pl. VIII. fig. 2, *a*), which is stoloniferous, and collectively (fig. 1, *ff*, and fig. 2) of the same, forming a reticulated structure in which the chambers are united to each other by the stolons (fig. 2, *b*). Chamber or lobe varying in shape from globularity to any kind of multiangulate figure, which may be produced by a variable number of stolons dragging out its convex surface in different directions into angular forms, so as in the aggregate to effect a reticulated structure in which the chambers are represented by the knots and the stolons by the interuniting cords of the net (fig. 1, *ff*). Chambers or lobes varying in size under 1-360th inch in diameter; stolons cylindrical, about 1-1800th inch in diameter, varying in length with the distance between the chambers which they connect. The projecting angles of neighbouring chambers often uniting directly, so that two or more become continuous without the intervention of stolons (fig. 1, *g*, and fig. 2, *e e*). Some are dark brown and others calc-white (what the brown colour arises from I am unable to say). Externally furnished (chiefly on the convex side or that opposite the stolons) with a number of delicate, straight, hair-like tubuli about 2-6000ths inch long and almost of immeasurable thinness (fig. 2, *c c c*), each of which projects

from a base about 1-1200th inch in diameter, apparently situated in the centre of a polygonal grain of calcite about 2-6000ths inch in diameter (fig. 3, *a* and *b*). Grains of calcite forming in apposition the structure of the chamber-wall, which is therefore very thin (fig. 4, *a*). Internally filled with a reticulated structure (fig. 4, *b*, and fig. 5, *a*), the larger interstices of which are in many instances occupied by a spherical cell (? reproductive body) (fig. 6, *g* &c.) varying under 4-6000ths inch in diameter. In the confined state parasitically extending into the cells of *Orbitolites Mantelli*, var. *Theobaldi*, which it infests, when each lobe or chamber of the parasite occupies a single cell in the central plane of this Orbitolite and is successively connected with its neighbours, chain-like, by a single stolon (fig. 1, *c*, and fig. 6, *h*), while instead of following the circular linear arrangement of the cells of the Orbitolite, the chain-like development frequently leaves it obliquely in a zigzag form (fig. 1, *e*); or in the free state (fig. 1, *ff*) spreading out independently in the reticulated one above mentioned among the sand &c. of the stratum in which the Orbitolites have been deposited, now more or less held together by a matrix of crystalline calcite, which in the *polished* fragment admits of the *Ramulina* in its free state being seen at different depths below the surface.

Loc. The bed of *Orbitolites Mantelli*, var. *Theobaldi*, in the west bank of the Irrawadi, 6 miles below Thayetmyo, in Burma ('Annals,' 1888, vol. ii. p. 342).

Obs. This microscopic form so prevails in the bed of the Orbitolites just mentioned, that it is hardly possible to subject a small fragment of the latter, which has been polished for an opaque object or ground down to a thin translucent slice, to microscopic examination without observing several portions of it; while its chief habitat appears to have been in and about the cells of the test of this species of Orbitolite, which is the only species of large Foraminifera in the deposit. So like is the chamber with its straight tubuli to the cells and their interuniting tubuli, of which the *crust* of the Orbitolite is composed, except that the tubuli in the former are only on one side, that it is often difficult to distinguish the difference; but that it is a distinct structure is confirmed by its growth in parts *only* of the central plane, as above mentioned, and its occurrence over part of the "crust" in the microscopic section of the "crust" and central plane together, where the contrast between the two is unmistakable. Of course all that is peculiar to it *now* in a lapidified state must have taken place before it thus became perpetuated by fossilization.

Although parasitic it was evidently a species of Foramini-

fera closely allied to the subfamily Ramulininæ, of which Dr. Brady has given several figures in his 'Challenger' Report (Zoology, vol. ix. text, p. 587, pl. lxxvi. figs. 22–28, 1884); but being "microscopic" it is of course almost infinitely smaller than the specimens of the recent species (viz. 1-15th inch) which Dr. Brady has described and delineated under the name of "*R. globulifera*," as well as the fossil ones (viz. 1-16th inch) previously found in the Chalk of the north of Ireland by Mr. J. Wright, and figured in the Report of the Belfast Nat. Hist. Field Club for 1873–4 (pl. iii. figs. 19 and 20).

The appearance of this fossil in its reticulated form (fig. 1, *ff*) also so much resembles that of the reticulated structure presented by similar phases of development in the Mycetozoa of de Bary (see M. C. (now Dr.) Cooke's 'Myxomycetes of Great Britain,' 1877, pls. iii., iv., and viii. figs. 24, 27, and 82 respectively), that one cannot help thinking that the Foraminifera must resemble them in other respects, especially in their stages of reproduction, if not in their elementary composition, since many of them develop calcareous material to such an extent in their structure that Rostafinski, in his classification ('Monograph of the Mycetozoa,' 1875), has made an order of them under the name "Calcareæ" (Cooke, *op. cit.* p. 2), which de Bary has illustrated in *Physarum leucophaeum* ('Morphologie und Biologie der Pilze,' 1884, p. 469, fig. 191).

Let us now compare the development of the spore or reproductive body of the Mycetozoa with that of the Foraminifera through the *freshwater* naked and testaceous Rhizopoda, adopting the same stages numerically in each to facilitate the comparison.

Thus, (1) the spore of the Mycetozoa is spherical, varying about 1-4000th inch in diameter, consisting generally of a dark brown cortex filled with colourless granuliferous plasma; (2) on germination the cortex bursts and the granuliferous plasma comes forth in the form of a colourless, monociliated, polymorphic body, possessing a nucleus and a contracting vesicle (see de Bary's figures, *op. cit.* p. 454 &c.); (3) the cilium is retracted and the polymorphic body assumes the condition of an Amœba; (4) after this the now *un*ciliated bodies flow together and thus become massed into a state which is called the "plasmodium," still presenting active polymorphism; (5) this activity gradually ceases and a motionless condition follows under which the plasmodium subsides into a more or less flat cake-like form (in *Æthalium septicum* &c.), when the whole of the interior passes from a

colourless into an opaque, brown, dust-like mass, consisting of the spherical spores just described grouped together into variously shaped compartments constructed by flocculent septa, while in other forms, e. g. *Stemonites* &c., portions of the plasmodium are thrown up into stipitate heads (sporangia of exquisite form and structure according to the species) whose contents undergo similar changes to those of the *Æthalium* just mentioned; in short the plasmodium becomes transformed into the adult form of the species, whatever that may be; this bursts, and the spores becoming free follow the same process in germination as that above described, whereby the life-history of the Mycetozoan is completed.

Directing our attention next to the freshwater naked and testaceous Rhizopoda, which, through the Gromiidæ, such as *Gromia fluviatilis*, Duj.*, are most intimately connected with the Foraminifera on the one hand, and in their polymorphic plasmodia &c. so much resemble the Mycetozoa on the other, it will be seen that in 1856–57 I described and illustrated the tests of *Amœba verrucosa* and *Euglypha alveolata* in an effete state, respectively charged with a number of spherical colourless cells similar in form and composition to the spores of the Mycetozoa ('Annals,' vols. xviii. and xx. pls. v. and i. figs. 26 &c. and 13), and following their stages of development after the same manner as that adopted for the spore of the Mycetozoa, it has been found that:—

(1) The spore or reproductive body of these Rhizopoda is spherical, about 1-1366th inch in diameter in *Amœba verrucosa* ('Annals,' 1857, vol. xx. p. 40, pl. i. fig. 13, *a*, *b*) and about 1-4000th inch in *Euglypha alveolata* (*ib.* vol. xviii. p. 244, pl. v. figs. 27 and 28), also that it consists of a transparent colourless cell-wall or cortex filled with equally colourless granuliferous plasma. (2) On germination (which has not been actually seen) the cell-wall or cortex may be fairly inferred to burst, as in the Mycetozoa, and the granuliferous plasma to come forth in the form of a colourless monociliated polymorphic body, possessing a nucleus and a contracting vesicle. (3) The cilium becomes retracted and the polymorphic body assumes the condition of an Amœba. (The presence of the cilium and its retraction in the young Rhizopod has been seen in the instance of a mother-cell in which the progeny came forth one by one in the form of monociliated polymorphic bodies, retracted their cilium respectively, and, putting forth pseudopodial rays, assumed the form of an *Actinophrys*

* With the marine species I have nothing to do here

('Annals,' 1857, vol. xix. p. 261). But it can hardly be doubted that the polymorphic spore does in such instances always come forth in a monociliated condition, while the mere retraction of the cilium is of common occurrence.) (4) After the retraction of the cilium the now *un*ciliated bodies flow together in the Mycetozoa, and thus becoming massed produce the "plasmodium." This again has not been witnessed in the freshwater Rhizopoda, unless the groups of *Actinophrys* and the conjugations of *Difflugia*, in which I have found as many as five individuals together ('Annals,' 1872, vol. ix. p. 421), be taken as instances of it. What the object of this "flowing together" may be generally has not been discovered; but in the Mycetozoa it leads to the evolution of the particular form which the species finally assumes and the development of the spores or reproductive bodies. (5) The activity of the Rhizopod ceases after it has attained its adult form and the reproductive bodies have been developed, when, as in the Mycetozoa, the body becomes effete and the reproductive bodies become free. The latter then germinate and the life-history of the freshwater naked and testaceous Rhizopoda is also thus completed.

Of course it is comparatively easy to witness the germination of the spores of the Mycetozoa, because the species containing them are so large as to be capable of being handled, while the spores are so abundant in them that when torn to pieces they produce a dust (as before stated) which soils the fingers like *soot*, hence the name *Æthalium*. On the other hand, the freshwater Rhizopoda are microscopic objects which can only be satisfactorily seen under a high power and only occasionally with reproductive bodies or spores in them; hence, again, it is only when they are testaceous, e. g. *Euglypha* (which has an unmistakable form of test), that the young or small ones can be recognized; and this has been done by myself in one or more instances where the same vessel has contained a number of the adult forms more or less charged with the reproductive bodies ('Annals,' 1856, vol. xviii. p. 230, pl. v. figs. 26–31 &c.).

Turning now to the Foraminifera, we find:—(1) That the spore or reproductive body appears to consist in like manner of a "round ball" composed of granuliferous plasma presenting in the aggregate a dark colour, held together by the natural coherency of the mass rather than by any specialized membrane. Max Schultze found such in the chambers of "living" Rotaliæ in great abundance and of various sizes, less than the diameter of the siphon (? stolon) which connects the chambers, say about 1-3000th of an inch, as seen in the soft

parts of a mounted specimen of *Operculina arabica* that I still possess, from which the calcareous material of the test had been removed by acid ('Organismus der Polythalamien,' 1854, p. 27, *a*, *b*); and two years afterwards he verified this in a species of *Miliola* (Müller's 'Archiv,' 1856, nos. 1 and 2, p. 165, Taf. vi. B). In 1861 I found the same kind of thing, but in a fossilized state, in a specimen of *Nummulites Ramondi* about one fifth of an inch in diameter, infiltrated with ochraceous oxide of iron, which thus renders the whole of the structure in a vertical section through the centre, when polished and overspread with Canada balsam under a glass slip particularly brilliant and distinct. (I am not now alluding to the "opaque scarlet spherules," to which I have lately called attention.) In this condition the last chamber especially is observed to be filled with spherical bodies about 1-1800th inch in diameter, translucent, and charged with light brown granular contents ('Annals,' 1861, vol. viii. pl. xvii. fig. 15). This preparation I still possess. So much, then, for the reproductive body in the Foraminifera. (2) The germination of this "body" has not been actually observed; but, like that of the freshwater Rhizopoda just mentioned, it may fairly be inferred to be similar to that of the spore in the Mycetozoa. (3) The retraction of the cilium would follow as a matter of course, and the plasmic contents thus become amœbiform. (4) But the "flowing together" of the amœbiform bodies to form a "plasmodium" is still less evident than in the freshwater Rhizopoda, for the development after the soft or plastic condition of the reproductive body of the species, especially in the Nautiloid forms, can be followed from the commencement to the end, through the plasmic chambers or lobes as they are successively produced becoming permanently represented in their forms by shell-substance.

At what period the reproductive bodies begin to appear in this development remains to be discovered. But as regards the possibility of the reproductive body germinating in the chamber of the parent, Dr. Strethill Wright's statement in 1861 may be noted ('Annals,' vol. vii. p. 362), viz. that he had seen "three small living *Spirillinæ*" in *S. perforata*, apparently confirming what Ehrenberg had noticed in 1841, which led the latter to call the species "*vivipara*." Here again I found the same kind of thing in a *fossilized* state in an infiltrated specimen of *Nummulites Ramondi* about one fifth of an inch in diameter, treated in the same way as that above described; that is to say, in the outer chamber, close to one angle of the vertical section, there are several bodies which

appear to be elements of reproduction in a state of germination, only one of which, however, has so far advanced as to produce a test which is recognizable, and this is a Nautiloid form consisting of the primary cell and two following chambers, altogether measuring about 1-360th inch in its longest diameter; so that if the surface of the section presents one of these the whole cavity may contain many more; nor does it appear likely that this one had come from the exterior, for besides the apparently closed and unfractured state of the chamber it is not likely that the reproductive body would return for germination to that or any other chamber of the Nummulite in which it was produced.

By what course the reproductive bodies of the Foraminifera are eliminated also remains to be discovered, or whether the test becomes effete like that of the Mycetozoa and fresh-water Rhizopoda. That the latter appears to be the case is indicated by the great number of empty tests and the few filled with the living animal that I found in the bed of *Operculina arabica* on the south-east coast of Arabia ('Annals,' 1852, vol. x. p. 168), and especially by the beds of Nummulites whose enormous thicknesses have given rise to the term "Nummulitic Series."

Thus *Ramulina parasitica* in an evolutionary point of view seems to be an initiatory form of the Foraminifera, and in organization ranks with the Mycetozoa and the fresh-water Rhizopoda.

N.B.—The type specimens referred to in the above paper, consisting of a slide and a small thin fragment about 13-12ths by 7-12ths inch square, polished on both sides, have been deposited in the Geological Department of the British Museum, and the two large "hand-specimens" from which they were taken, marked "H. 47. 83" and "H. 47. 84" respectively, have been returned to the museum of the Geological Survey of India at Calcutta. Also the type specimens to which I have referred in each of my last six papers in the 'Annals' have been deposited in the same department of the British Museum.

EXPLANATION OF PLATE VIII.

N.B.—All the illustrations are necessarily more or less diagrammatic, from the minuteness of the objects, but with as little deviation from the natural characters as possible.

Fig. 1. *Ramulina parasitica*, n. sp., lobes varying under 1-360th inch in

diameter. Diagrammatic sketch taken from a slice of *Orbitolites Mantelli*, var. *Theobaldi*, reduced to translucent thinness and cut a little obliquely, so as to show part of the central plane overlain by the *crust*. *a*, cells of the central plane; *b*, cells of the crust; *c*, globular lobes of the *Ramulina* confined to the cells of the central plane and joined together by a common stolon; *e*, the zigzag form; *f f*, lobes in the "free state" more or less multiangular and joined together by stolons, presenting in the aggregate a reticuliform character like that of the capillitium of some of the Mycetozoa; *g*, lobes united together directly.

Fig. 2. The same. Portion in the "free state," more magnified, to show:—*a*, the lobe or chamber; *b*, the stolon; *c c c*, tubuli projecting from the surface of the chamber; *d*, chambers below the surface unfinished; *e e*, two chambers united together. Taken from the polished surface of a fragment of the rock containing the said *Orbitolites*, where the chambers of the *Ramulina* appear at different depths in the transparent crystalline matrix. (On most of the chambers the tubuli are omitted for perspicuity and to save trouble in drawing.)

Fig. 3. The same. Single chamber, more magnified, to show the tubuli and their position on the surface *in situ* (fig. 3 *a*). Fig. 3 *b* represents a small fragment of the surface of the chamber magnified to the scale of 1-48th to 1-3000th of an inch, to show that the bases of the tubuli are respectively situated in the centre of grains of calcite, which appear to have a polygonal shape.

Fig. 4. The same. Two chambers, much magnified. Taken from the surface of the polished fragment, where their upper parts have been ground off, thus showing *a*, the thinness of the wall, and *b*, the reticulated structure in the interior of the chamber, at the same time.

Fig. 5. The same. Group in which both sides of the lobe, *a*, have been ground down, thus again showing the reticulated structure of the interior, but by transmitted light; *b*, one in which the section has not gone below the surface, showing the truncated ends of the tubuli; *c*, unfinished lobe. Taken from a microscopic slice which had been reduced to translucency.

Fig. 6. The same. Five cells of the central plane obliquely cut across, so as to show the structure of the globular lobes which they respectively contain *gradationally*. *a*, cells of "central plane;" *b*, opaque state of "globular lobe" uncut; *c*, showing indistinctly traces of the (?) reproductive bodies which it contains; *d*, the same more distinct; *e*, the same still plainer; *f*, the thinnest section of all, in which the reproductive elements appear to consist of spherical cells, *g*, imbedded in the reticulated tissue; *h*, stolon. All the parts of this illustration are magnified to the scale of 1-48th to 1-6000th inch and taken from a mounted microscopic slice.